

SNS Progress Review



Linac Design & Commissioning

J. Stovall, J. Billen, S. Nath, H. Takeda, L. Young,
R. Shafer, K. Crandall & J. Galambos

7 March 2000



Linac Design Status

- DTL Physics design is complete
 - Cavity cold-modeling started
- CCL Physics design is complete
 - Cavity cold-modeling is continuing to finalize geometry & tuning
 - Hot-model pending cold-modeling results
- SRF Reference design is complete
 - Cavity layout is frozen
 - Investigating alternate phase & quad laws

Linac Design Status



- Interfaces
 - MEBT-DTL: dimensions are frozen, matching is complete
 - DTL-CCL: dimensions are frozen, matching is complete
 - CCL-SRF: dimensions are frozen, have a matched solution
 - SRF β_1 - β_2 : have a matched solution
 - SRF-HEBT Bend: length frozen, have a matched solution, details under study

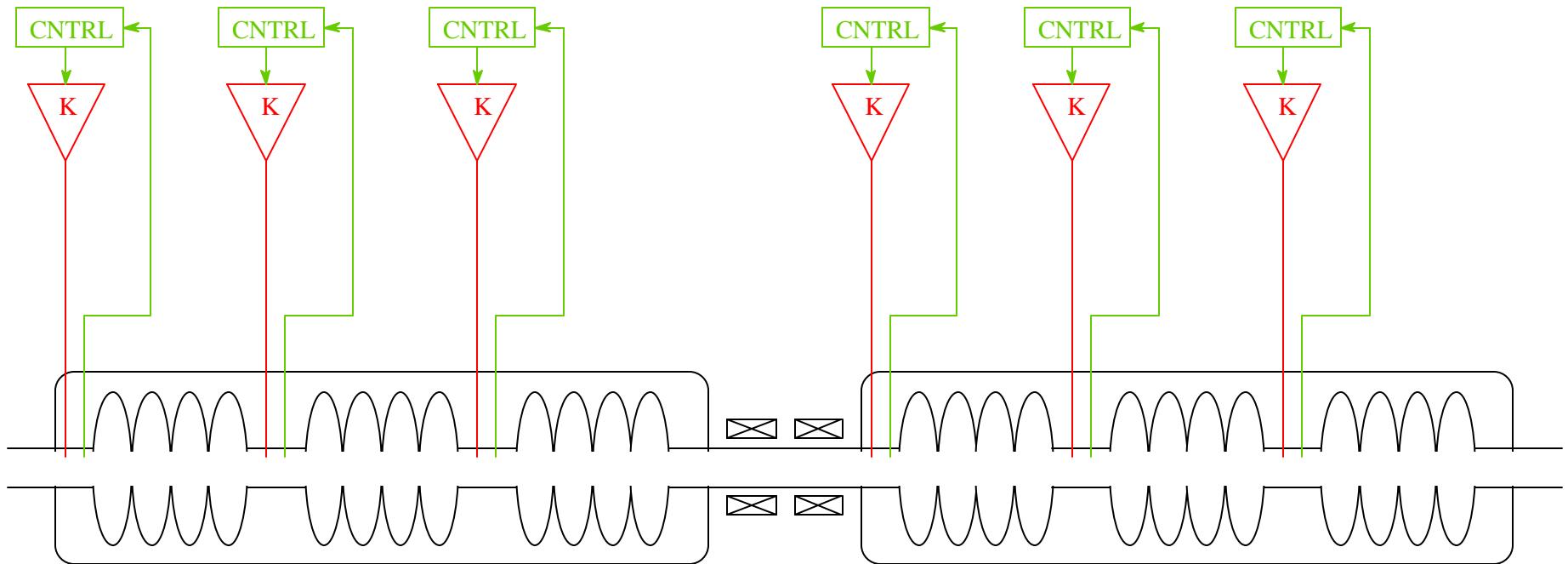
Linac Architecture Summary



Structure	W _{final}	Total Length	Cells per Cavity	Cavities per Module	Modules	No of Klystrons	Structure Length
	MeV	m					m
DTL	86.8	36.6	60 to 21		6	6	36.6
CCL	185.6	91.9	8	12	4	4	55.4
SRF I	382.2	157.7	6	3	11	33	64.2
SRF II	972.3	276.0	6	4	15	59	118.4
RF upgrade	1251.1	323.4	6	4	6	25	47.3

Structure	HVPS	HVPS Power	Transmitters	Klystrons	Klystron Power
		MW			MW
RFQ & DTL	3	10	7	7	2.5
CCL & HEBT	6	10	6	6	5.0
SRF I & II	8	10	16	92	0.55
SRF upgrade	3	10	6	25	0.60

SRF Baseline: 1 Cavity/Klystron, Individual Cavity Control

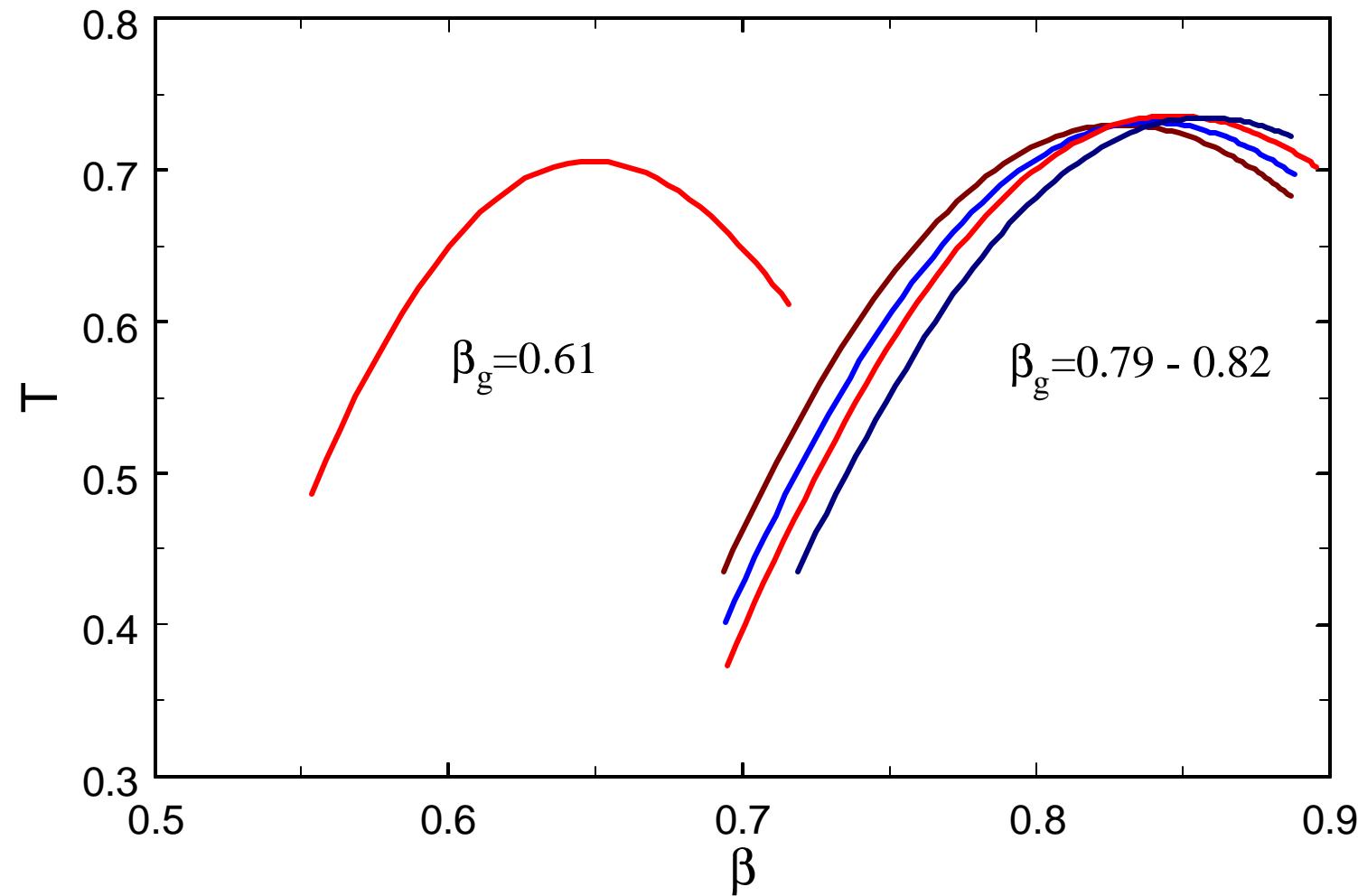


SRF Design is Based on 2 Cavity b



- $E_{\max} \leq 27.5 \text{ MV/m}$
- Optimized for cost with 2 β cavities
 - a 3rd lower β cavity would be too numerous & inefficient
- $\beta_1 \equiv 0.61$
 - based on earlier 2-cavity design studies
 - 5 MW CCL modules coarsely quantize initial energy
- $0.74 \leq \beta_2 \leq 0.82$
 - higher β provides more efficient acceleration
 - i.e. higher E_0 , T & L_{cav}
 - if $E_{\max} > \langle E_{\max} \rangle$, higher β supports a higher W_{final}
- Transition energy
 - maximized final energy for fixed cost machine

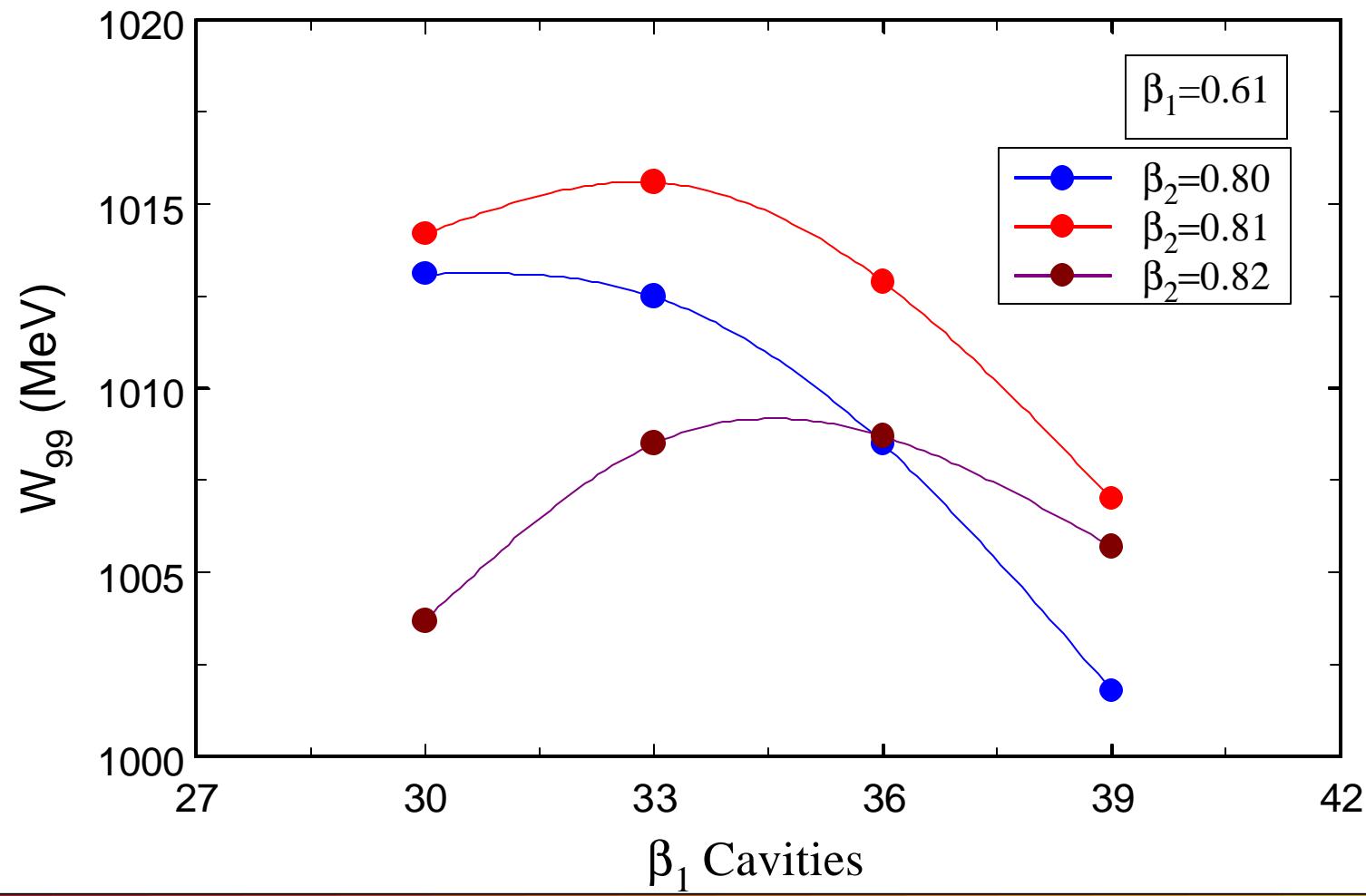
Transit Time Factors (T_{ave}) for Candidate Cavities Increase With b



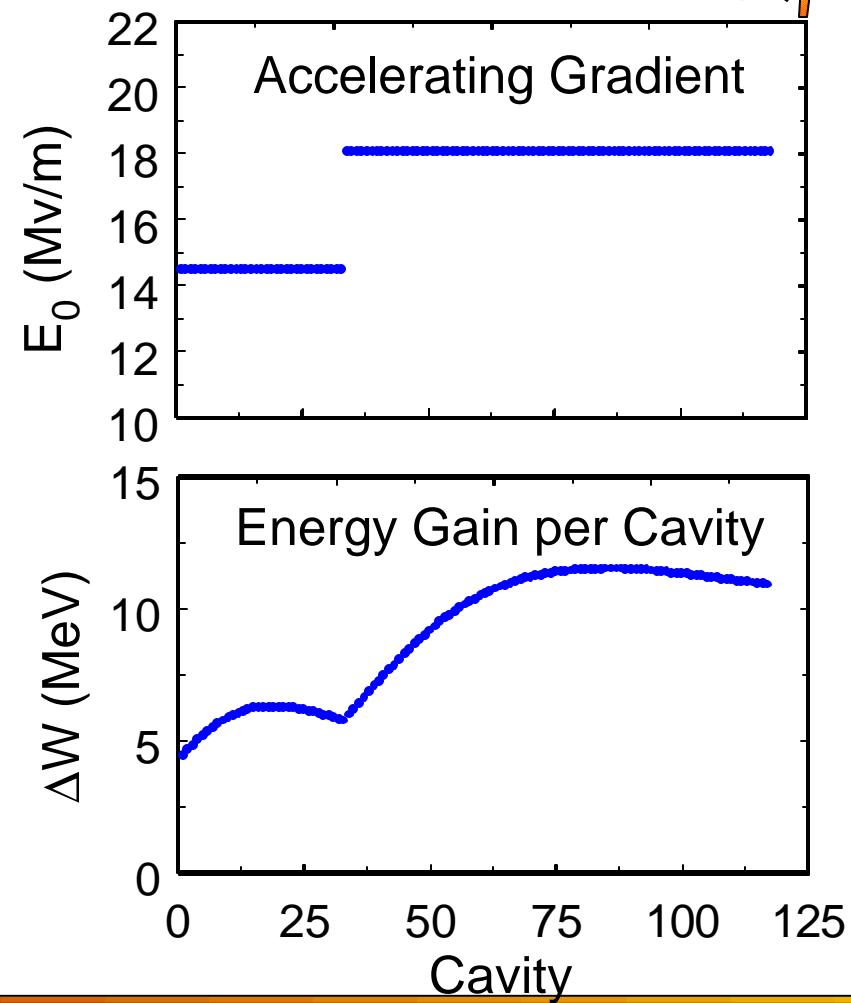
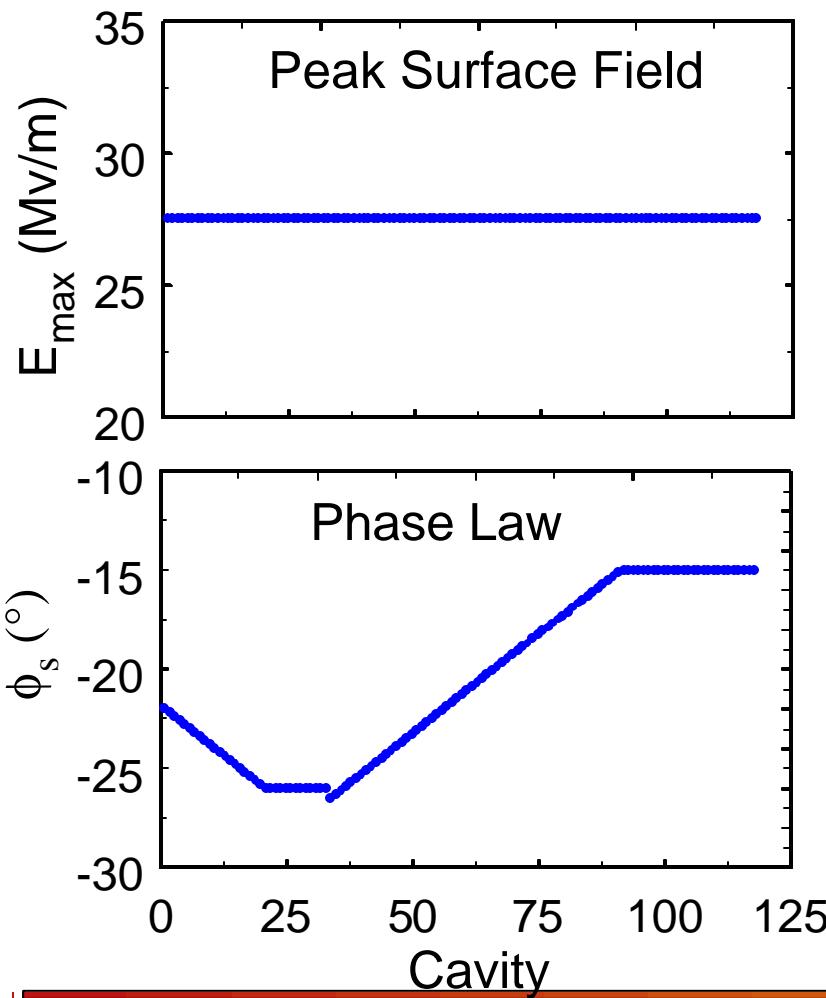
SNS Linac

Los Alamos

Cavity b & Transition Optimization for a Linac Having 99 Total Cavities



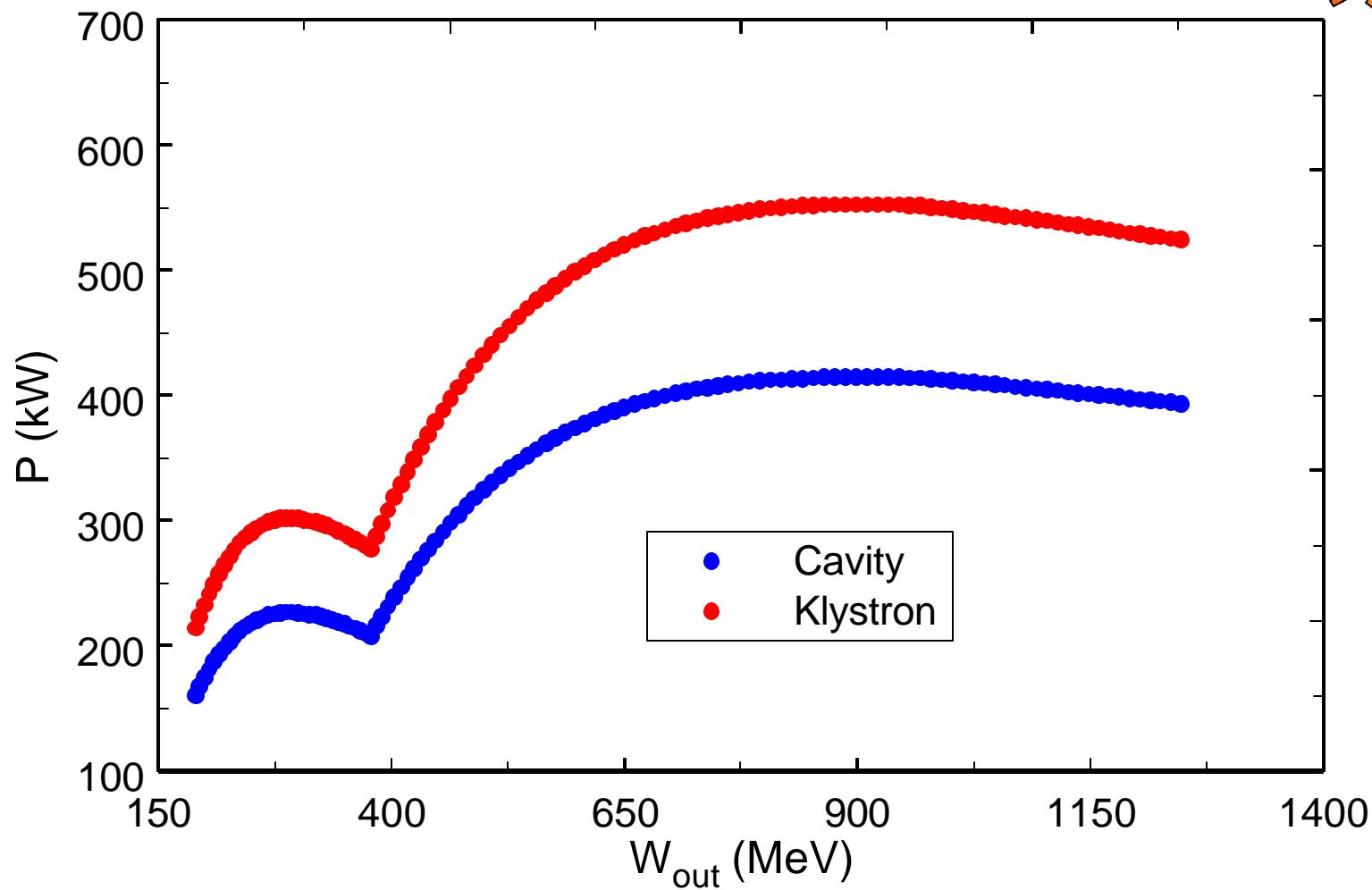
SRF Linac Design Parameters



SNS Linac

Los Alamos

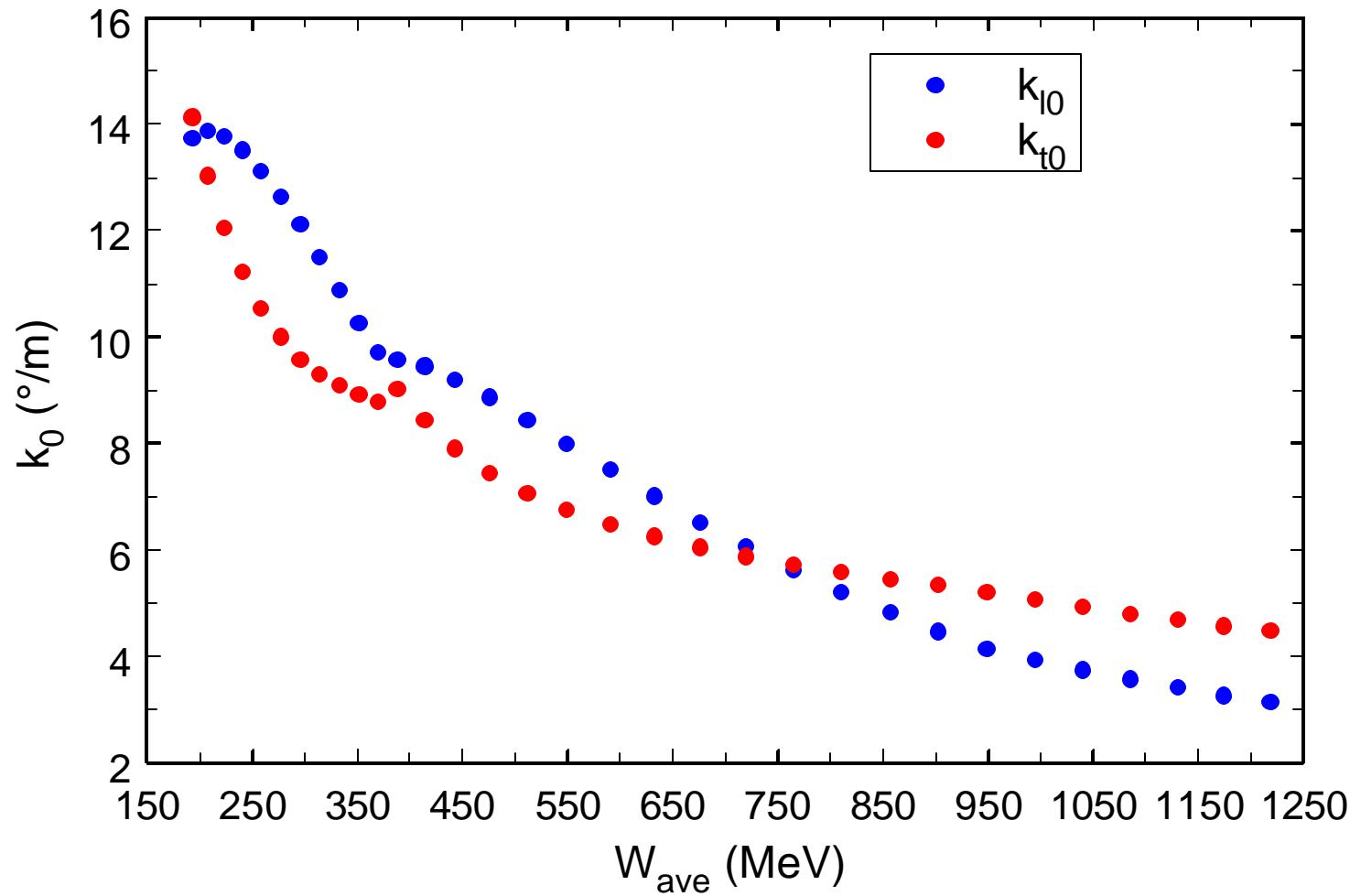
Beam Consumes 75% of Available rf Power



SNS Linac

Los Alamos

SRF Real-Estate Zero-Current Phase Advance is Smooth & Continuous



SRF Phase & Amplitude Setpoints Preserve Longitudinal Dynamics



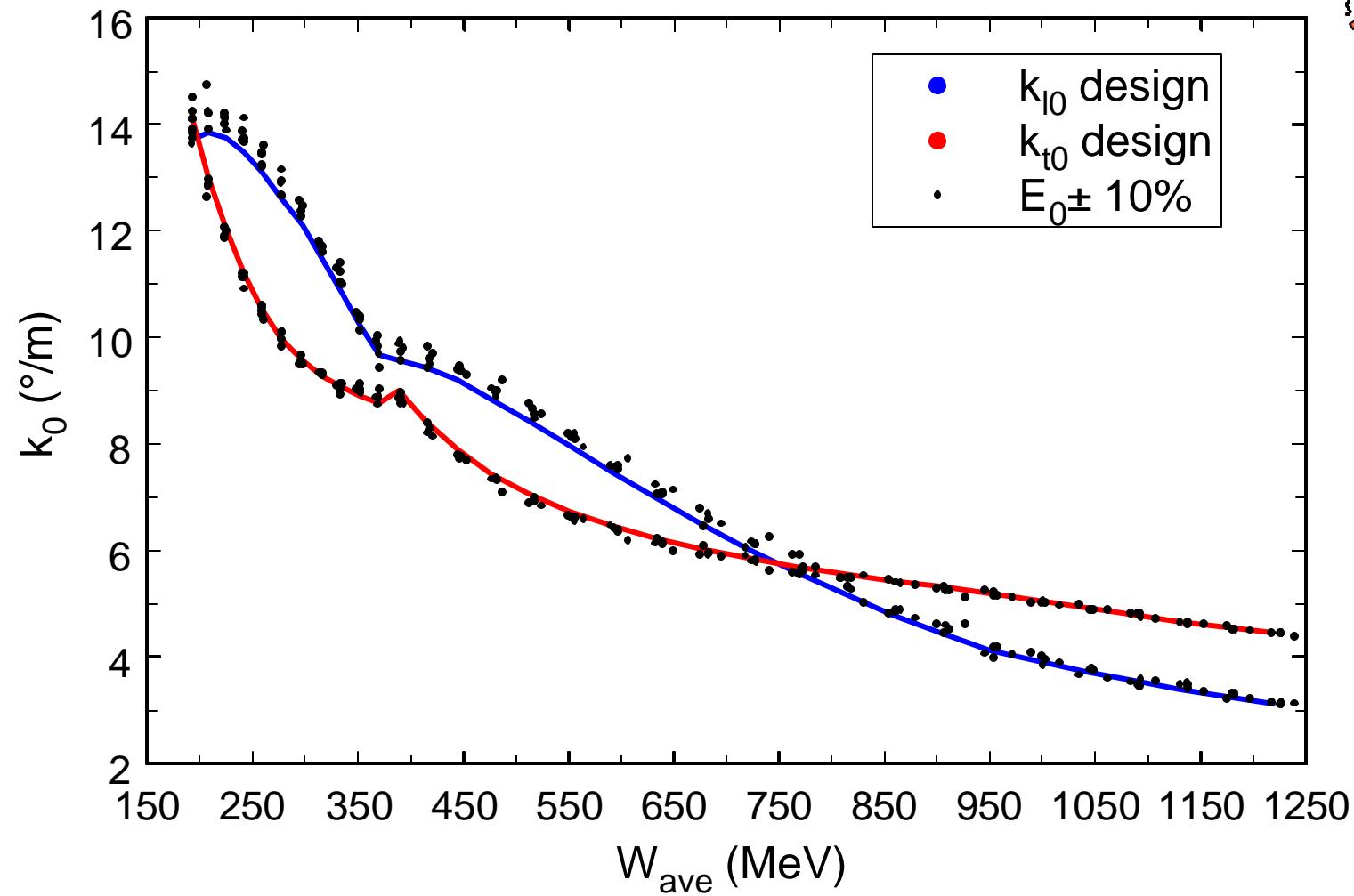
- E_{\max} determined at acceptance for each cavity
 - $\langle E_0 \rangle \approx E_{\text{dsn}} \pm 10\%$
- Calibrate cavity field probes
 - using drifting beam to excite cavities
- $E_{0,\text{operating}}$ established for each cavity
- Corresponding $\phi_{\text{operating}}$ derived for each cavity
 - preserving longitudinal dynamics
 - holding $k_{0,I}$ constant
 - $k_{0,I}^2 \equiv E_{0,\text{design}} T(\beta) \sin(\phi_{\text{design}} / \beta^3 \gamma^3)$
 - $\phi_{\text{operating}} = \beta^3 \gamma^3 \sin^{-1}(k^2/E_{0,\text{operating}} T)$

SRF Linac Will Have 184 Static Field Errors Effecting W_{final}

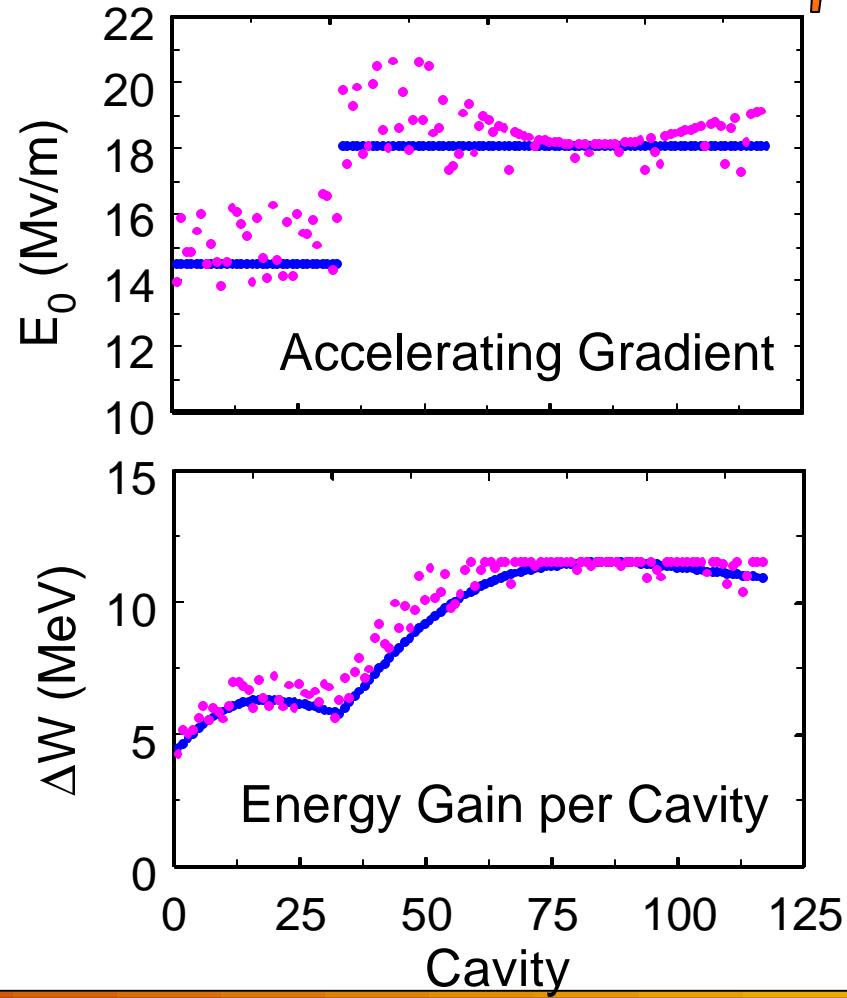
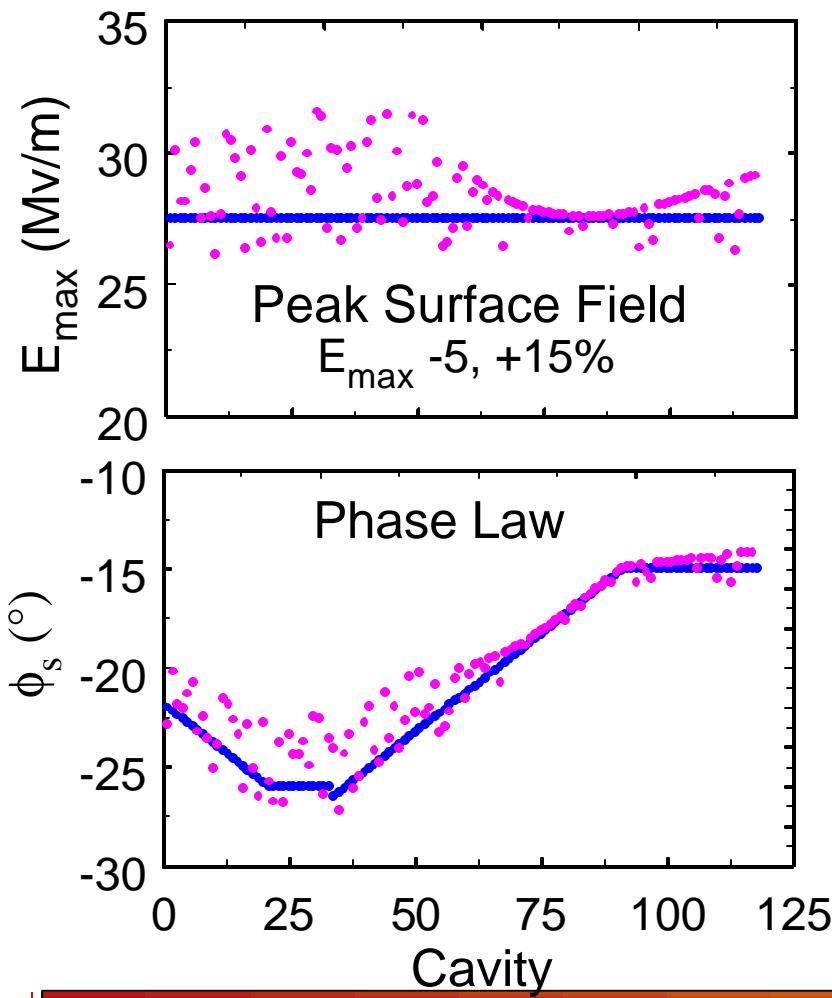


- Design cavity field: $E_{0,\text{design}}$
- Actual cavity field: $E_{0,\text{operating}} = E_{0,\text{design}} \pm 10\% \text{ nom}$
- Field measurement error: $E_{0,\text{measured}} = E_{0,\text{operating}} \pm 5\% \text{ nom}$
- Design cavity phase: ϕ_{design}
- Phase set-point: $\phi_{\text{setpoint}} = f(\phi_{\text{design}}, \beta, E_{0,\text{measured}})$
- Phase measurement error: $\delta\phi = \pm 2^\circ$
- Actual cavity phase: $\phi_{\text{operating}} = \phi_{\text{setpoint}} \pm 2^\circ$

Tuning Philosophy ($k_{0,i}=\text{const}$) Preserves Beam Dynamics



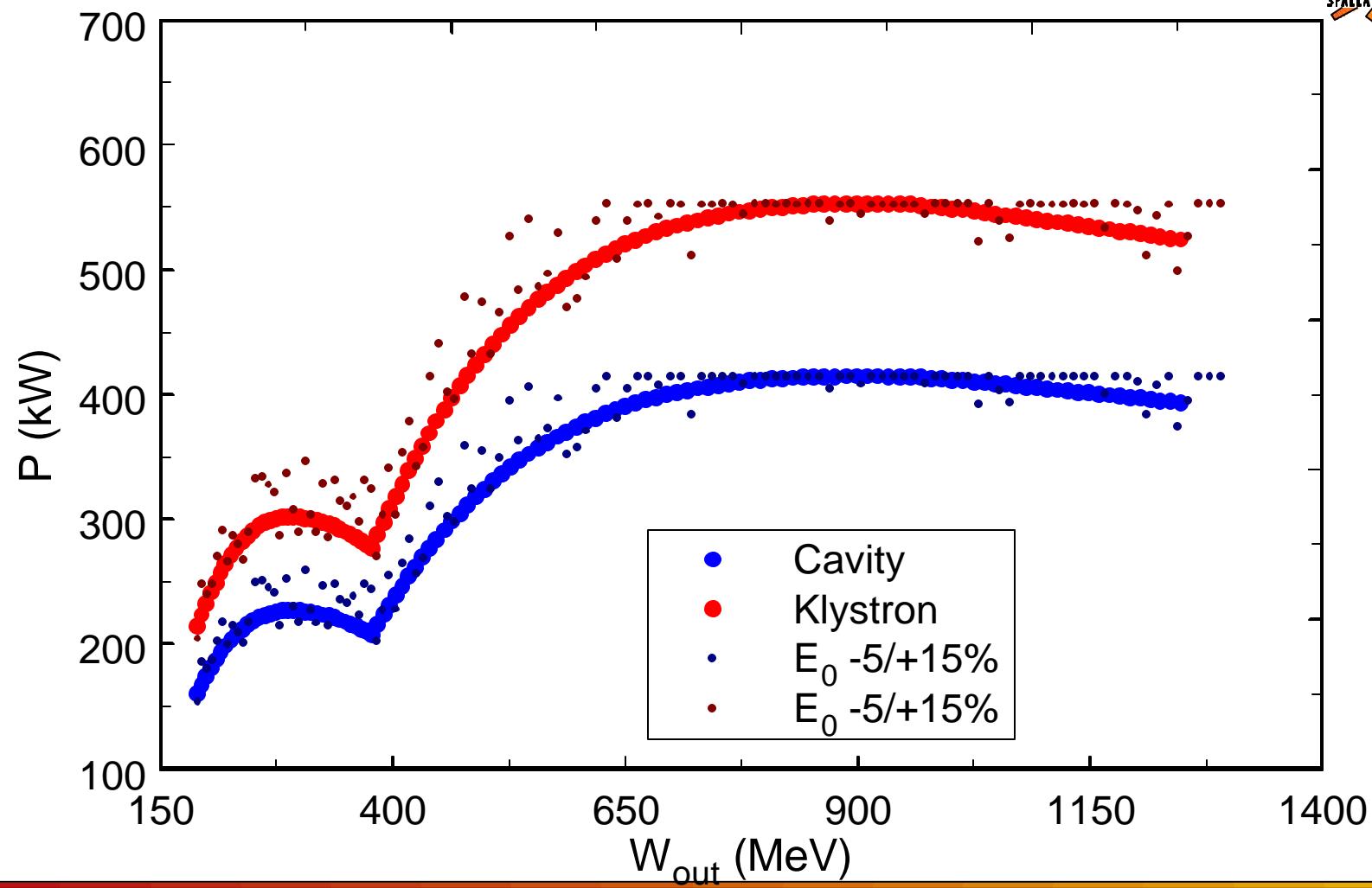
SRF Operating Example for a Representative Set of Cavities



SNS Linac

Los Alamos

W_{final} is Limited by E_{max} & Installed rf Power



SNS Linac

Los Alamos

Physics Issues from Previous ASACs



- CCL to SRF pumping section
 - included, matched, interface drawing issued
- Transverse steering errors
 - steering algorithms modeled for DTL, CCL & SRF
 - algorithms are not yet included in multiparticle simulations
- Transverse & longitudinal mismatch
 - all interfaces are matched
 - errors causing mismatch are included in simulations
 - techniques to correct for mismatch are under study

Physics Issues from Previous ASACs



- End-to-end simulations with errors & large realistic beam distributions:
 - 10k LBL distributions used in all error studies (56 mA)
 - RFQ now modeled with PARMTEQ
 - arbitrarily large distributions are now available
 - minor RFQ-MEBT matching required
- Failure/recovery scenarios: TBD
- Commissioning / tuning algorithms
 - steering: complete for all sections
 - matching: TBD
 - rf
 - MEBT, DTL & CCL: TBD
 - SRF: tuning scheme developed

Code Development Required



- Asymmetric SRF cavity (4 die) fields
 - assume symmetric fields
- Asymmetric cryomodule
 - Assume uniform cavity orientation
- Steering algorithms, all sections
 - add to PARMILA
- Field set point algorithms, all sections
 - add to PARMILA
- HEBT cavities
 - add to PARMILA
- SNS collaboration will use standard codes
 - agreed, modify to support UNIX platforms

DTL Tank 1 Commissioning Proposal



- With a “pencil” beam
 - Steer for transmission
 - Set rf phase & amplitude
 - Transverse acceptance
 - Match injected beam
 - Transverse emittance
 - Energy centroid
 - Energy spectrum (?)
 - Repeat at full peak current
 - Sensitivity studies
 - Test operational diagnostics
 - Production beam demonstration
-

DTL Tank 1 Commissioning

Diagnostics



- Beam current transformer
- Faraday cup
- Energy degrader
- Profile monitor (wire scanner)
- Emittance (slit & collector)
- Beam position & ϕ monitors (BPM)
- Vu screen
- Spectrometer (?)
- Production beam stop (16 kW)

DTL Tank 1 Commissioning Beams

Nominal Parameters



Measurement	I _{peak}	i	PRF	P _{peak}	P _{ave}
	mA	μsec	Hz	kW	W
Profile	52	50	10	390	133
Faraday cup	52	100	10	390	265
Emittance	52	100	10	390	265
Current toroid	0.1-100	1-1000	1-60		
Pencil beam	5	50	10	19	30
Production	52	1000	60	390	16,000

DTL Tank 1 Commissioning

~22 Independent Variables



- MEBT
 - buncher phase (4)
 - buncher amplitude (4)
 - steering (2 pr)
 - quads (~4)
 - beam aperture (~3)
- DTL
 - phase (1)
 - amplitude (1)
 - steering (3 pr)

CCL & SRF Ideograms Communicate Diagnostics Architecture



- Communicates:
 - physics requirements
 - engineering design constraints
- Prioritize real-estate usage
- Straw man for:
 - power supply lists
 - cabling lists
 - device naming

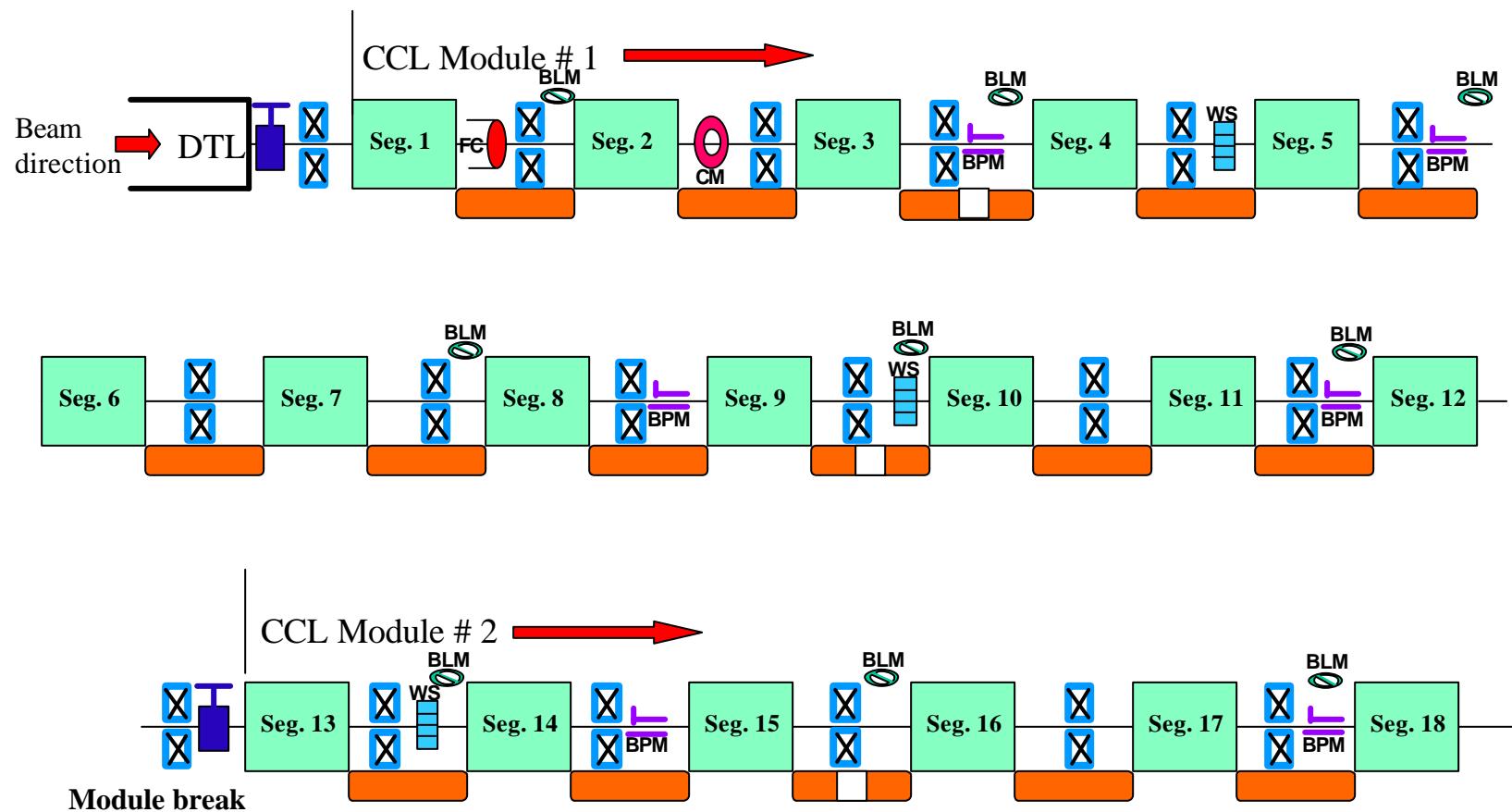
CCL/SRF Diagnostic Ideogram

Draft

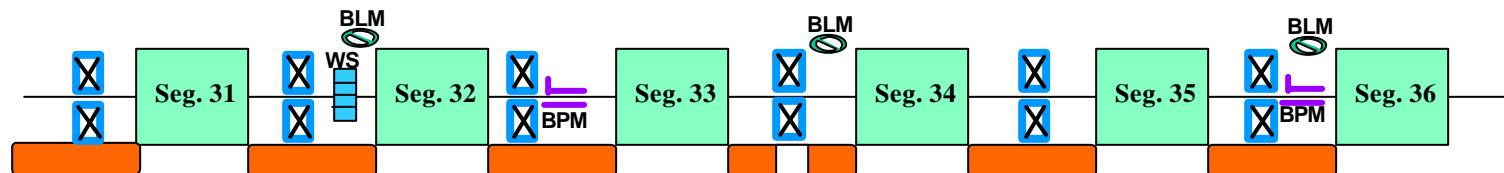
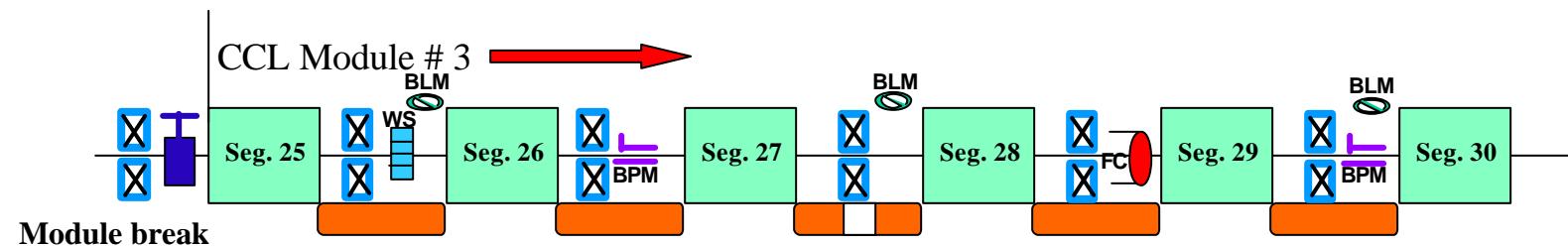
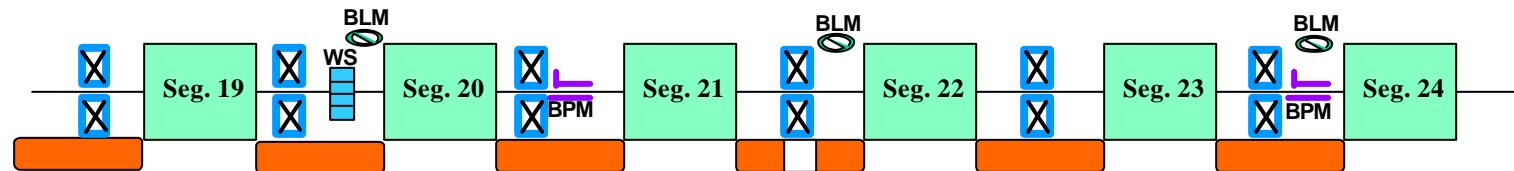


Symbol	Name	Number of units	Symbol	Name	Number of units
	CCL Segment	49		BPM / Phase detector	49
	Powered Bridge coupler	8		Current Monitor (CM)	3
	Non-powered Bridge coupler	36		Beam stop (Faraday cup)	3
	Quadrupole	50		Wire Scanner	42
	Gate Valve	64		Beam Loss Monitor	56
	Fast Valve	7		Electrostatic Precipitator	2
	Cryomodules, Beta = 0.61	11		Cryomodules, Beta = 0.81	15

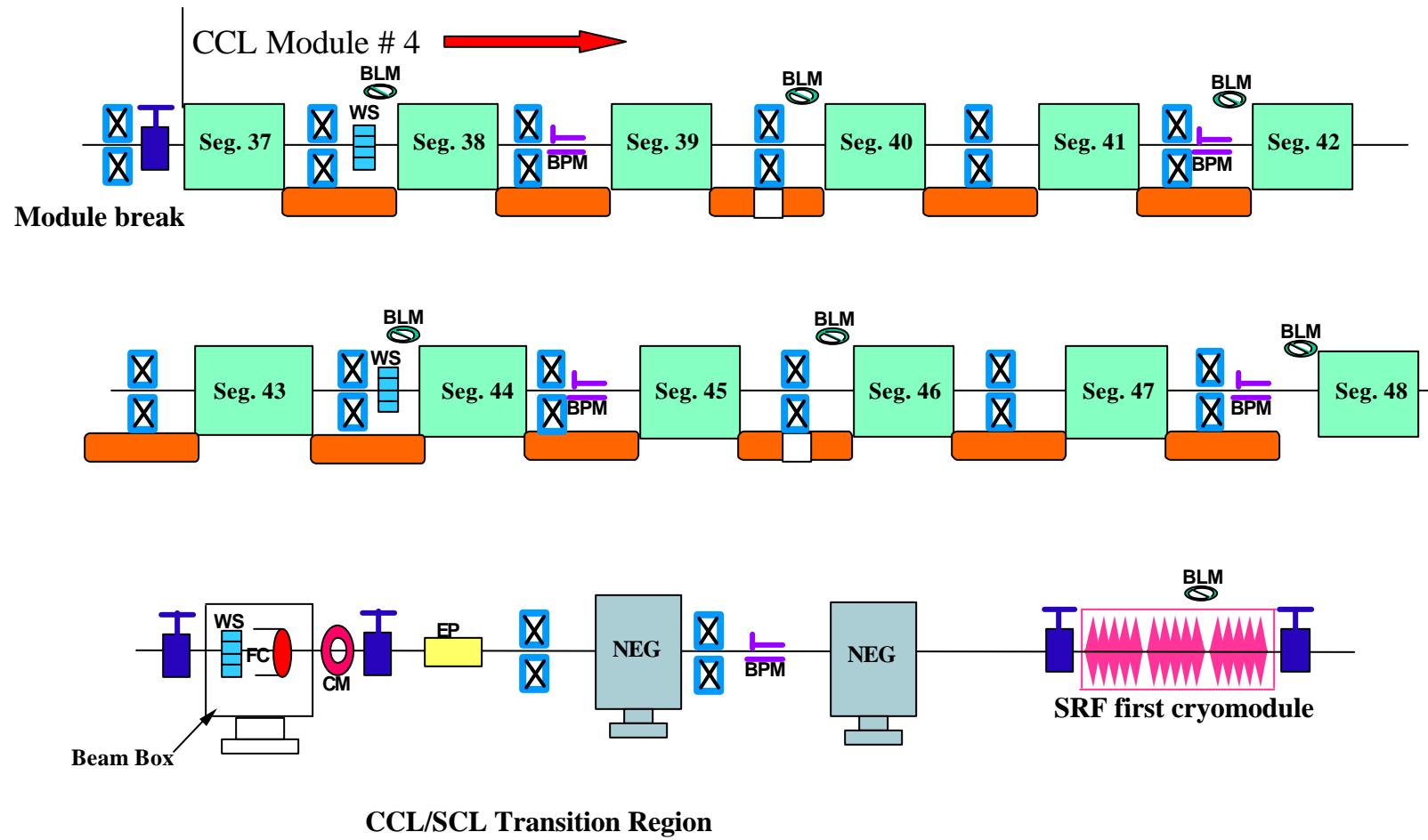
CCL/SRF Diagnostic Ideogram



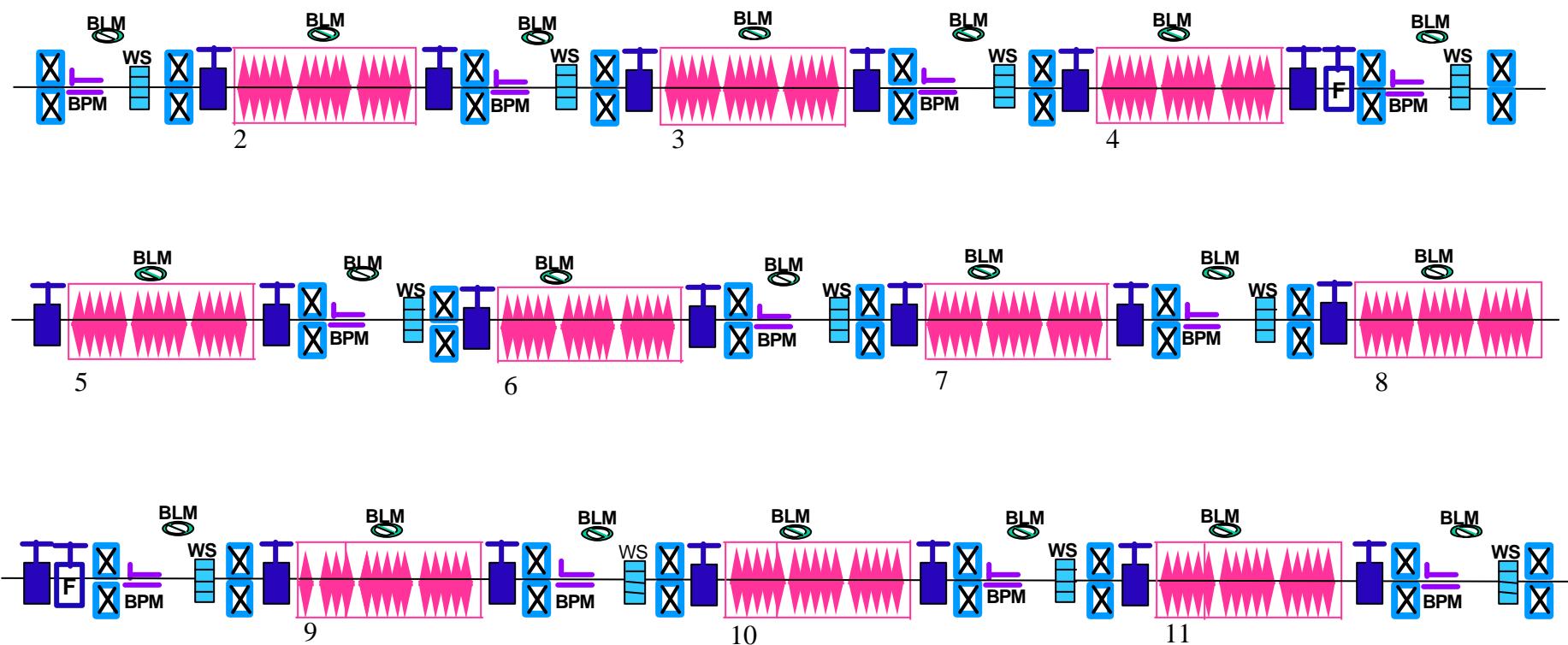
CCL/SRF Diagnostic Ideogram



CCL/SRF Diagnostic Ideogram



CCL/SRF Diagnostic Ideogram

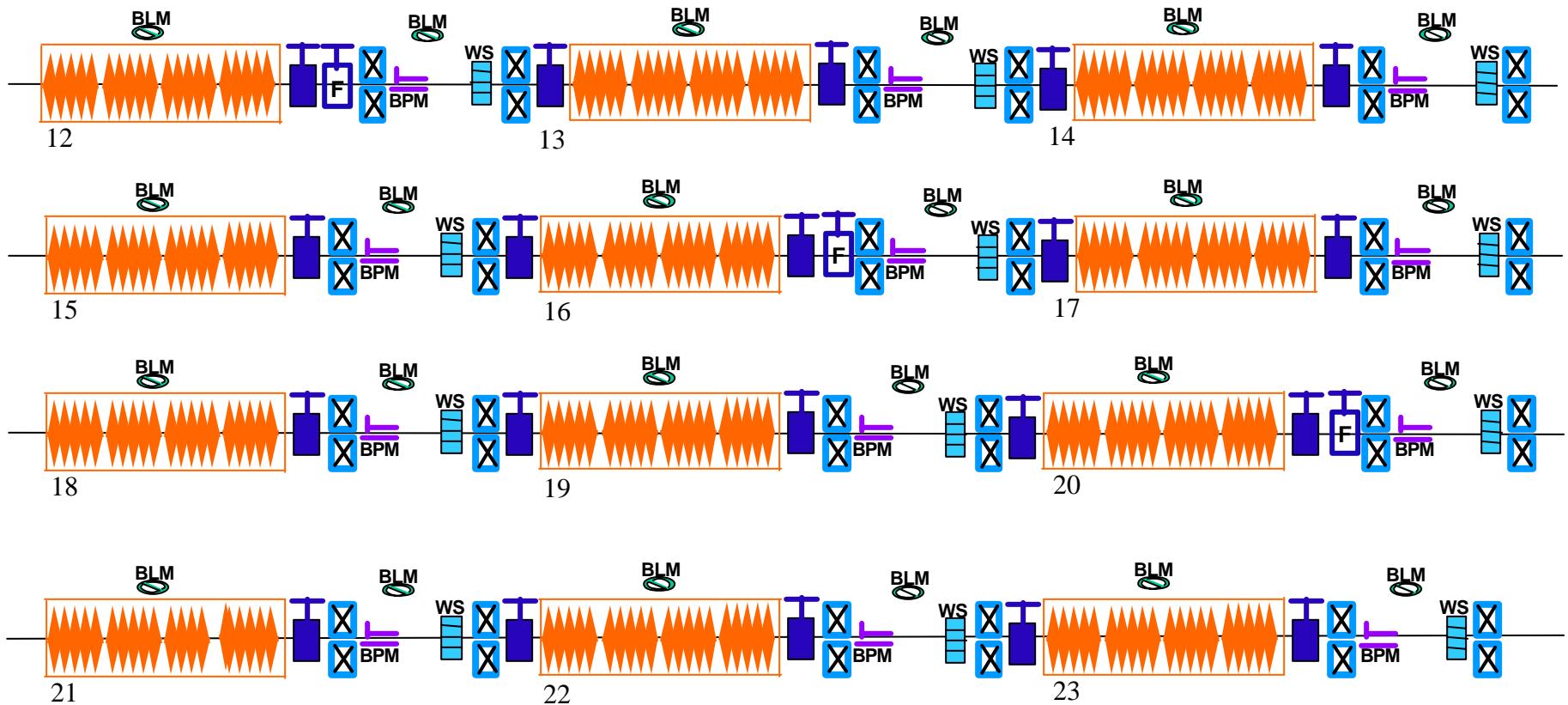


Z. Chen / 8 - 21 - 00

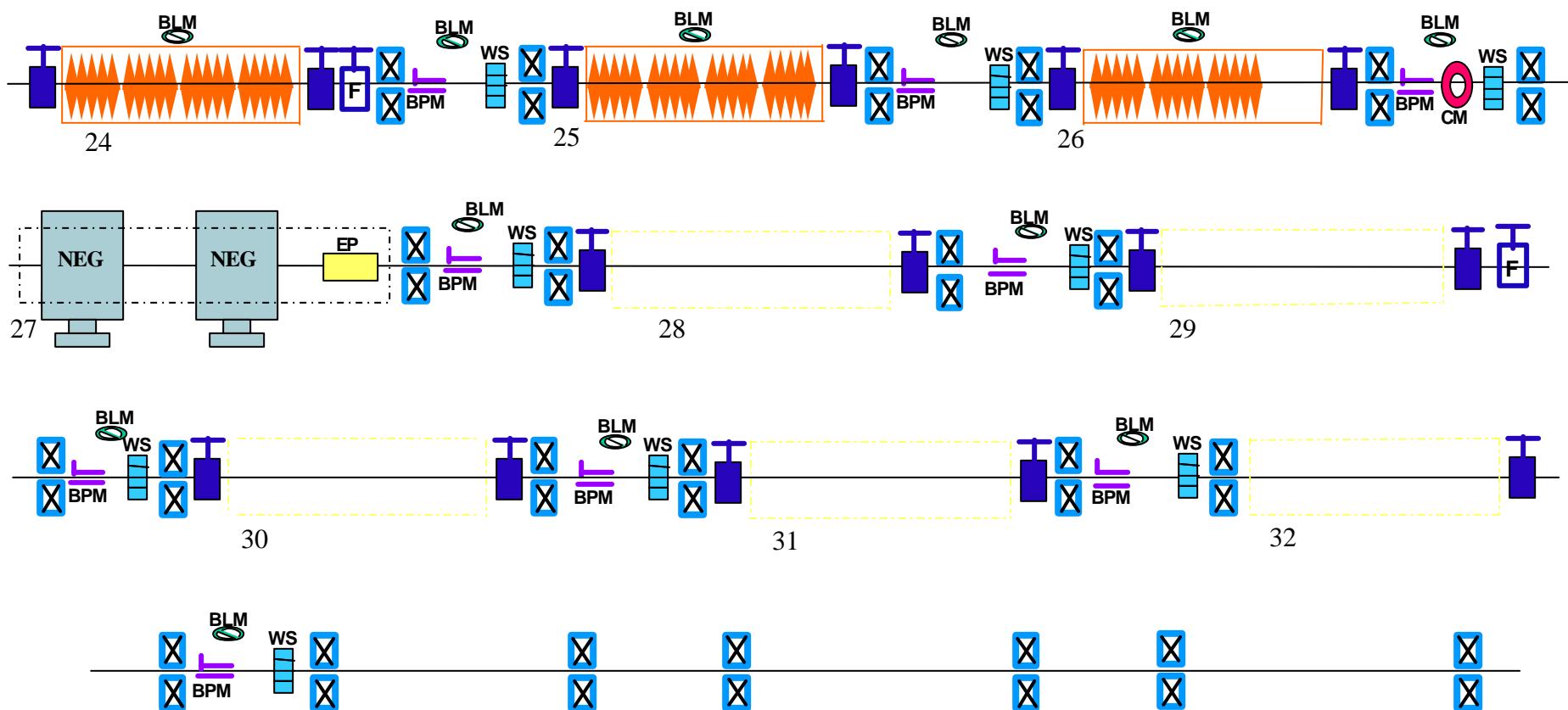
SNS Linac

Los Alamos

CCL/SRF Diagnostic Ideogram



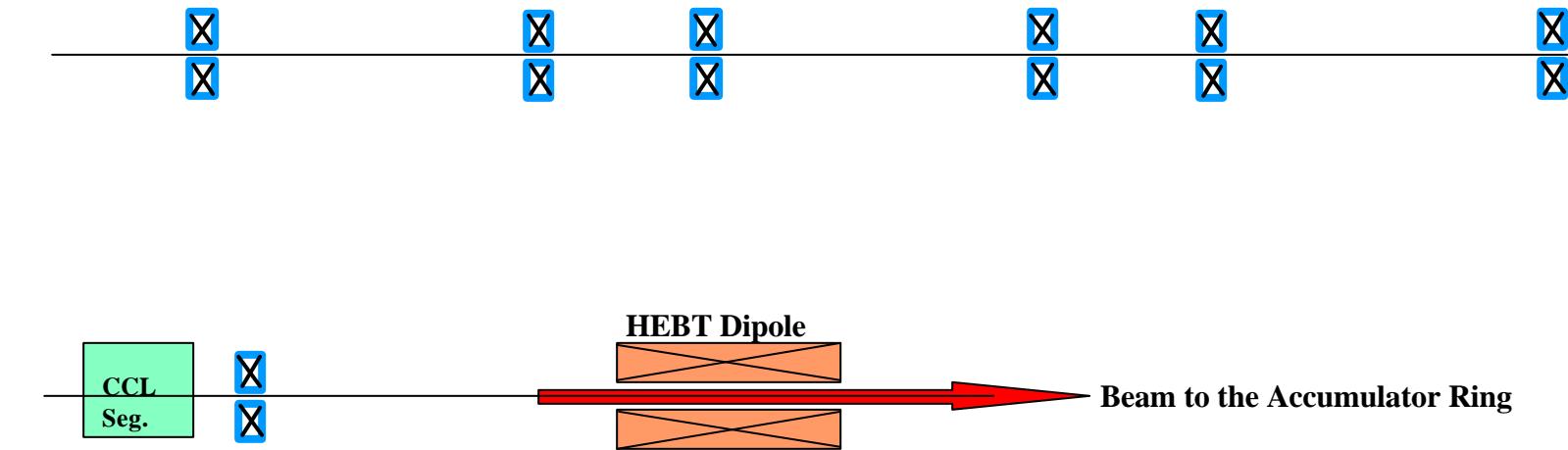
CCL/SRF Diagnostic Ideogram



SNS Linac

Los Alamos

CCL/SRF Diagnostic Ideogram



SNS Linac

Los Alamos